Processing method for 2024 aluminium alloy

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Abstract of **GB2352453**

An aluminium alloy comprising (in % by weight): copper 3.8-4.5, magnesium 1.2-1.5, manganese 0.3-0.5, silicon <0.25, iron <0.20, zinc < 0.20, chromium, titanium and zirconium <0.10 each comprises hot rolling with an input temperature of 430-470{C (preferably with an exit temperature >300{C), cutting into sheets, solution treating at 480-500{C for five minutes to one hour, quenching (preferably in water) and forming by means such as stretching, drawing, flow spinning or bending. The alloy may be homogenised at 460-510{C for 2-12 hours, it may be cold rolled and/or annealed at 350-450{C. The sheet may be clad on one or both sides, e.g. with a 1xxx series aluminium alloy. Sheet made by this process is of particular use in manufacturing aircraft fuselage panels.

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(54) Abstract Title
Processing method for 2024 aluminium alloy

(57) An aluminium alloy comprising (in % by weight): copper 3.8-4.5, magnesium 1.2-1.5, manganese 0.3-0.5, silicon < 0.25, iron < 0.20, zinc < 0.20, chromium, titanium and zirconium < 0.10 each comprises hot rolling with an input temperature of 430-470°C (preferably with an exit temperature > 300°C), cutting into sheets, solution treating at 480-500°C for five minutes to one hour, quenching (preferably in water) and forming by means such as stretching, drawing, flow spinning or bending. The alloy may be homogenised at 460-510°C for 2-12 hours, it may be cold rolled and/or annealed at 350-450°C. The sheet may be clad on one or both sides, e.g. with a 1xxx series aluminium alloy. Sheet made by this process is of particular use in manufacturing aircraft fuselage panels.

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METHOD OF MANUFACTURING FORMED PIECES OF TYPE 2024 ALUMINIUM ALLOY

TECHNICAL FIELD OF THE INVENTION

This invention relates to a method of manufacturing highly worked pieces for mechanical engineering, and in particular aircraft construction, implementing type 2024 AlCuMg aluminium alloy sheets according to the Aluminum Association's registration.

STATE OF THE ART

2024 alloy is widely used for aircraft construction and its composition registered with the Aluminum Association is as follows (weight per cent): Si < 0.5 Fe < 0.5 Cu: 3.8 - 4.9 Mn: 0.3 - 0.9 Mg: 1.2 - 1.8 Zn < 0.25 Cr < 0.10 Ti < 0.15.

In addition to the characteristics usually required for aircraft construction, such as high mechanical strength, toughness, resistance to crack propagation, etc., certain pieces, especially those made by stretch forming, drawing, flow spinning, bending or roll forming, require sheets with good forming ability.

Patent EP 0 473 122 describes a method of manufacturing alloy sheets composed of (weight per cent): Cu: 4 - 4.5 Mg: 1.2 - 1.5 Mn: 0.4 - 0.6 Fe < 0.12 Si < 0.05, including intermediate annealing at a temperature > 488°C. It teaches that these sheets have improved toughness and resistance to crack propagation in comparison with conventional 2024.

Patent application EP 0 731 185 describes sheets of modified 2024 alloy, subsequently registered with the Aluminum Association as 2024A, showing a reduced level of residual stress and improved toughness for thick sheets, and improved elongation for thin sheets. This application limits Mn content to 0.55% and Fe content to 0.25%, with the relation: $0 < Mn - 2\ Fe < 0.2$ (Mn and Fe content being expressed in %).

Patent application WO 96/29440 describes a method of manufacturing a product of type 2024 aluminium alloy, comprising hot rolling, annealing, cold rolling, solution treatment, quenching and minimum cold working, which may be stretching, planishing, or flattening, a process for improving forming ability. Having established that using a pure base (very low iron and silicium content) and with a manganese content of less than 0.5% improves forming ability, the application recommends a preferred alloy composition: Cu: 4.0 - 4.4, Mg: 1.25 - 1.5, Mn: 0.35 - 0.5, Si < 0.12, Fe < 0.08, Ti < 0.06. The intermediate annealing between hot rolling and cold rolling is described as favorable for mechanical strength and toughness. However, this additional and unusual process step has economic drawbacks. Furthermore, it does not solve the problem posed by the market, i.e. to supply sheets with characteristics such that the forming thereof be simplified.

PROBLEM POSED

In order to reduce manufacturing cost, aircraft builders are trying to minimize the number of sheet

forming steps, and to use sheets that can be manufactured economically using short working chains, i.e. including as few individual steps as possible. For fuselage panels, the present practice of aircraft builders is to supply hot or cold rolled sheets according to the required thickness, as manufactured ("F" temper according to the EN 515 standard) or in soft temper ("O" temper) or in as quenched and aged temper ("T3" or "T4" temper), to submit them to solution heat treatment followed by quenching, then to form them and submit them to natural or artificial aging, so as to obtain the required mechanical characteristics.

In general, after solution treatment and quenching, the sheets are in a temper characterized by good forming ability, but this temper is unstable ("W" temper), and forming must take place in as quenched condition, i.e. within a short time after quenching, roughly from about ten minutes up to a few hours. If this is not possible for production planning reasons, the sheet metal must be stored in a cold chamber at a sufficiently low temperature and for a sufficiently short duration in order to avoid natural aging. For bulky and highly formed pieces, this solution heat treatment requires large furnaces, making the operation awkward, including with respect to the same operation performed on flat sheet metal. The possible need for a cold chamber increases the costs and drawbacks of the state of the art. For highly worked pieces, this operation may have to be repeated, if the material, in its present metallurgical temper, does not have

sufficient forming ability allowing the desired shape to be obtained in a single operation.

Starting from F temper, the only possible forming is roll forming. The roll formed sheet metal is then solution treated and quenched, and a second forming is carried out either in as quenched condition, or after storage in a cold chamber. Under all other circumstances, the sheet metal is directly solution treated and quenched before forming. When the starting point is O temper sheet metal, a first forming operation is carried out from this temper, and a second forming after solution treatment and quenching. This alternative is used when the target forming is too significant to be performed in a single operation from W temper, but may still be carried out in two passes starting from O temper. In this temper, the sheet metal is admittedly less workable, but the O temper is easier to use than the W temper, which is unstable, and requires additional heat treatment. However, manufacturing sheet metal in O temper calls upon final annealing of the sheet metal as rolled, and therefore an additional manufacturing step, which is contrary to the objective of simplification this invention is aiming at.

Under certain circumstances, even when starting from W temper sheet metal, which generally has better forming ability, it is possible to avoid using a second forming step after solution treatment and quenching; this is the third alternative of the method corresponding to prior art.

This way of working 2024 alloy sheets by deep forming and, if required, in as quenched condition, tends to develop more and more in as far as there is a tendency towards larger individual pieces in order to reduce the number of assemblies, which meets objectives, both technical (assemblies give rise to corrosion and fatigue cracks) and economical (the assembly operation represents an important share of aircraft manufacturing cost). Moreover, using large pieces allows to reduce aircraft weight.

Under all circumstances, during the last working, damage tolerance properties are deteriorating under the influence of strain hardening associated with this strain.

The object of the invention is therefore to simplify the method of manufacturing formed pieces, and in particular pieces highly worked in one or more processes, such as stretch forming, drawing, flow spinning, or bending, by associating an optimized chemical composition and specific manufacturing methods, allowing to avoid as much as possible solution treating formed sheet metal.

Obviously, every new method of manufacturing highly worked pieces must result in pieces with mechanical and performance characteristics that are at least as good as existing products.

It is another object of the invention to obtain pieces with damage tolerance properties that do not deteriorate after strain.

OBJECT OF THE INVENTION

The object of the invention is a method of manufacturing highly worked pieces of 2024 type AlCuMg alloy, comprising the following steps of:

a) casting a plate composed of (weight per cent):
Cu: 3.8 - 4.5 Mg: 1.2 - 1.5 Mn: 0.3 - 0.5 Si < 0.10
Fe < 0.20 Zn < 0.20 Cr < 0.05 Zr < 0.03 Ti < 0.05

b) possibly homogenizing this plate at a temperature between 460 and 510°C, preferably between 470 and 500°C, for a duration of 3 to 6 hrs,

c) hot rolling at an input temperature between 430 and 470°C, and preferably between 440 and 460°C, in order to obtain a coil,

d) possibly cold rolling the coil,

e) possibly annealing the coil,

f) cutting the coil into sheets,

g) solution treating between 480 and 500°C, for a duration between 5 min and 1 hr,

h) quenching,

i) forming through stretch forming, drawing, flow spinning, or bending, wherein such forming may also take place after step f).

Preferably, the alloy has a copper content between 3.9 and 4.3% (and even more preferably between 3.9 and 4.2%), a magnesium content between 1.2 and 1.4% (and even more preferably between 1.25 and 1.35%), a manganese content between 0.3 and 0.45%, an iron content of < 0.10%, a silicium content of < 0.10% (and preferably < 0.08%), a titanium, chromium and zirconium content of < 0.07% (preferably < 0.05%). The inventive method allows for possibly using cladded plates, e.g.

sheets coated with a cladding of an alloy having better corrosion resistance, as is the case usually for aircraft fuselage coating sheets.

DESCRIPTION OF THE INVENTION

A first characteristic of the invention consists in using an alloy modified with respect to traditional 2024. The first modification consists in reducing the Si and Fe content to less than 0.25 and 0.20% respectively, and preferably to less than 0.10%. Furthermore, Mn content is also reduced to less than 0.5%, and preferably to less than 0.45%. Finally, Cu content is also slightly reduced and maintained at less than 4.5%, and preferably at less than 4.3%, or even 4.2%. Mg content is also slightly reduced, and maintained at less than 1.5%, preferably between 1.2 and 1.4%, or even between 1.25 and 1.35%.

The applicant has noted that this composition, suggested by prior art, does not as such allow to achieve the required forming ability.

The alloy is cast into plates, which may be homogenized at a temperature between 460 and 510°C (preferably between 470 and 500°C) for 2 to 12 hrs (preferably 3 to 6 hrs). Plates may be scalped. Hot rolling is done at an input temperature between 430 and 470°C, and preferably between 440 and 460°C. The output temperature of the coils is preferably at a higher temperature than the usual temperature, > 300°C, and preferably > 310°C, especially in case part of the forming is done before solution treatment.

After hot rolling, the coils are coiled. At this stage, they are elongated by more than 13.5%, and often more than 15% in the L and TL directions. They may be cold rolled if the required thickness cannot be achieved by hot rolling. Next, the coils are cut into sheets.

A first alternative of the invention consists in carrying out forming, through stretch forming, drawing, flow spinning, or bending, directly in this F temper without annealing or any other prior treatment. The partially shaped sheet is then solution treated at a temperature between 480 and 500°C for a duration between 5 min and 1 hr, then quenched, generally with cold water.

Forming takes place in two or more passes. The piece in as quenched condition (less than one hour) can immediately undergo another forming, or else it is transferred into a cold chamber at a temperature of less than 10°C, and preferably of less than 0°C, and formed after leaving the cold chamber. Sheets cladded on one or two sides can be used, as is the case most frequently for aircraft fuselage panels, cladded with an alloy of the 1000 series, e.g. the alloys 1050, 1100, 1200, 1135, 1145, 1170, 1175, 1180, 1185, 1188, 1199, 1230, 1235, 1250, 1285, 1350, or 1435.

A second alternative consists in carrying out the forming on sheets having undergone solution treatment and quenching. Forming can be done in T3 or T4 temper (quenched and aged with or without subsequent strain hardening), or, for more deeply worked pieces, in W temper, i.e. less than one hour after quenching, or on

a sheet stored in a cold chamber immediately after quenching.

In case sheets are used in T3 or T4 temper, such sheets are a compromise between mechanical strength and forming ability corresponding to at least one of the following sets of properties:

a) - a mean value of the three elongation A values measured in the directions TL, L and at 45°, greater than 20% and preferably greater than 22%, and

- a mean value of the three values $R_{p0.2}$ measured in the directions TL, L and at 45°, greater than 305 MPa, and

- an LDH value greater than 72 mm for a thickness of 1.6 mm, or an LDH value greater than 76 mm for a thickness of 3.2 mm, or an LDH value greater than 80 mm for a thickness between 4 and 7 mm.

b) - a mean value of the three values $R_{p0.2}$ measured in the directions TL, L and at 45°, greater than 305 MPa, and

- a mean value of the three values Ag measured in the directions TL, L and at 45°, greater than 18%.

c) - a mean value of the three elongation A values measured in the directions TL, L and at 45°, greater than 22%, and

- a mean value of the three values $R_{p0.2}$ measured in the directions TL, L and at 45°, greater than 305 MPa, and

- a mean value of the three values Ag % measured in the directions TL, L and at 45°, greater than 18%.

d) - a mean value of the three values $R_{p0.2}$ measured in the directions TL, L and at 45° greater than 305 MPa, and

- a mean value of the three flat stretching Atp values measured in the directions TL, L and at 45°, greater than 18%,

- an LDH value greater than 72 mm for a thickness of 1.6 mm, or an LDH value greater than 76 mm for a thickness of 3.2 mm, or an LDH value greater than 80 mm for a thickness between 4 and 7 mm.

These sheets in T3 or T4 temper have a forming ability characterized by at least one of the following three properties:

a) the LDH value is greater than 40 mm for a thickness of less than 4 mm, or greater than 74 mm for a thickness greater than 4 mm,

b) the forming limit diagram shows a coefficient $\varepsilon_1 > 0,18$ for L = 500 mm for a thickness between 1.4 mm and 2 mm,

c) the forming limit diagram shows a coefficient $\varepsilon_1 > 0,35$ for L = 500 mm for a thickness between 5.5 mm and 8 mm.

Moreover, they have improved properties of damage tolerance characterized by at least one of the following properties:

a) K_c (L-T) > 120 $MPa\sqrt{m}$

b) K_{c0} (L-T) > 90 $MPa\sqrt{m}$

c) K_c (T-L) > 125 $MPa\sqrt{m}$

d) K_{c0} (T-L) > 80 $MPa\sqrt{m}$

Pieces made from sheets both in T3 or T4 temper and in W temper show only very little deterioration of

damage tolerance after the last forming operation, if the amplitude thereof is less than 6%.

The various parameters used above, as well as the examples below, for characterizing forming ability, which is a generic term indicating the relative ease with which a metal is worked, are defined like this:

Starting with a uniaxial tensile test according to the EN 10002-1 standard, carried out for a sheet thickness greater than or equal to 3 mm with a proportional test piece having an initial length between marks Lo proportional to the initial sectional area So according to the relation $Lo = 5.65\sqrt{So}$, and for a sheet thickness of less than 3 mm with a type 1 non proportional test piece according to EN 10002-1, Table 4, the following parameters are obtained:

- $R_{p0.2}$: yield strength at 0.2% permanent elongation (MPa);
- R_m: ultimate tensile strength (MPa);
- A: elongation after failure (%), sometimes represented by the symbol "A%";
- A_g: non proportional elongation under maximum load, also called distributed elongation (%).

For each sheet, three different samplings are performed in general: in rolling direction (L direction), in long transverse direction (TL), and at 45° between the L and TL directions.

All the values resulting from a uniaxial tensile test are mean values obtained from two test pieces sampled in the same place.

Distributed elongation is the difference of elongation between the beginning and the end of the

plastic flow range, i.e. the permanent set range before contraction, of the strain curve.

Plane tensile elongation A_{tp} is the ultimate elongation during a so-called plane tensile test, wherein, in contrast to the uniaxial tensile test, it is arranged for the strain to have two dimensions, therefore in a plane, and not three dimensions, i.e. $\varepsilon_2 = 0$ instead of $\varepsilon_2 = -\varepsilon_1/2$.

The LDH (limit dome height) parameter is widely used for evaluating the drawing ability of sheets with thickness from 0.5 to 2 mm. It is the subject of many publications, in particular:

R. Thompson, "The LDH test to evaluate sheet metal formability - Final report of the LDH committee of the North American Deep Drawing Research Group", SAE conference, Detroit, 1993, SAE paper no. 930815;

R.A. Ayres, W.G. Brazier and V.F. Sajewski, "Evaluating the GMR limiting dome height test as a new measure of press formability near plane strain", J. Appl. Metalworking, 1979, vol. 1, pp. 41-49;

J.M. Story, "Comparison of Correlations between Press performance and Dome tests results using two dome test procedures", J. Appl. Metalworking, 1984, vol. 3, pp. 292-300.

The LDH test is a drawing test wherein the blank is clamped peripherally by a retaining ring. The pressure of the blankholder providing this clamping is 240 MPa. This blank, the size of which is 500 x 500 mm, is stressed by equiaxial bi-expansion. Lubrication between the punch and the sheet is provided by a plastic film and grease. The LDH value is the ultimate

punch displacement, i.e. the drawing near depth. Three tests are averaged.

The same method can be used to characterize the forming ability of thicker sheets (3 to 9 mm), but in this case, a larger tool (punch Ø = 250 mm) has to be used.

Resilience R_c is determined by a tensile bending test allowing to compare the resilience of various subtle differences (same sheet thickness) for a given strain.

A flat test piece of length L = 250 mm, width λ = 12 mm, and thickness 0.1 mm < e < 5 mm, is inserted between two self-locking clamping cheeks and tension maintained by means of a hydraulic jack, integral with the test mechanism. The predefined tensile stress is kept constant throughout bending, by means of the hydraulic servovalve regulation of the tension jack. The regulation loop incorporates the tensile stress by measuring via a piezoelectric transducer (Kistler washer). Tensile stress depends on the alloy and the thickness of the test piece.

A displacement transducer, connected to the acquisition computer, enables continuous test parameter control and calculates the test piece's bending angle. A forming punch, integral with the upper frame of the tension machine, is used as a support for the test piece. The bending angle used during the tests was 140°, for a punch with a radius r = 70 mm. Each folded sample is checked after disassembly using a sensor contour follower. This measuring apparatus allows to

evaluate the final angle as well as the radius of curvature obtained.

The stretching applied to the test piece, corresponding to the desired plastic flow, is determined using the rational tension curve by graphically noting the stress equivalent to the strain rate aimed at. The initial rate of strain, defining the bending stress, was kept constant during the test at 0.2%.

Resilience is given by the formula:

$$R_e = \frac{\alpha_f - \alpha_0}{180 - \alpha_0} \text{ where}$$

α_f = angle measured by the contour follower (°)

α_0 = angle measured during bending by the PC (°)

R_e = springback (0 for no springback and 1 for full springback).

The calculation using the radius of curvature yields less dispersed values and is performed as shown below:

$$R_e^1 = 1 - \frac{R_0}{R_f} \text{ where}$$

R_0 = punch radius

R_f = radius measured by the contour follower

R_e = springback (0 for no and 1 for full springback).

In practice, in order to facilitate the sequence and the fact of making forming operations more reliable, springback R_e as low as possible, ideally equal to zero, is sought.

The forming limit diagrams are determined according to the ISO 12004 standard (1987). Rectangular

formats, sized 500 x L (L being equal to 300 mm or 500 mm), are drawn according to the LDH test after a grid (2 x 2 mm^2 mesh) has previously been printed thereon. After drawing, the test with L = 500 results in: $\varepsilon_1 \cong \varepsilon_2$ (biaxial strain); after drawing, the test with L = 300 mm results in $\varepsilon_2 \cong 0$ (plane strain).

After failure, the formats are analyzed using the automatic CamSys system near the cracking area. The Asame-CamSys software makes it possible to create a mapping of the strains of the areas measured as described by J.H. Vogel and D. Lee "The automated measurement of strains from three dimensional deformed surfaces", J.O.M., vol. 42, 1990, pp. 8-13. Limit strains before local contraction are thus estimated and transferred onto a forming diagram with the coordinates ε_1 and ε_2.

Damage tolerance is characterized according to the ASTM E561 standard (curve R test). The test was carried out on test pieces with a center crack of width W = 400 mm for a crack length $2a_0$ = 133 mm. Both the critical plane stress by stress intensity factor K_c and the apparent stress intensity factor K_{c0} (sometimes also designated by the acronym K_{app}) are being measured.

EXAMPLES

Example #1

Various alloys were prepared, the compositions of which are indicated in Table 1. Rolling plates were cast, scalped, then homogenized at a temperature between 460°C and 510°C for 2 hrs to 12 hrs. After cladding with a 1050 alloy, the plates were hot rolled

up to a final thickness greater than or equal to 4 mm; for lower thicknesses, the coils were cold rolled. The sheets were characterized at the final thickness; the results are collected in Table 2.

Examples 1a, 1b, 1k, 1L, 1m, 1n, 1p, and 1q correspond to this invention. Examples 1c, 1d, 1e, 1f, 1g, 1h, 1i, and 1j correspond to prior art.

TABLE 1

Example	Cu (%)	Mg (%)	Mn (%)	Fe (%)	Si (%)	According to
1a	4.00	1.25	0.43	0.066	0.036	Invention
1b	4.03	1.28	0.41	0.07	0.04	Invention
1c	4.24	1.36	0.51	0.17	0.09	Prior art
1d	4.29	1.40	0.46	0.20	0.11	Prior art
1e	4.17	1.41	0.49	0.18	0.11	Prior art
1f	4.25	1.44	0.47	0.18	0.08	Prior art
1g	4.25	1.44	0.47	0.18	0.08	Prior art
1h	4.25	1.44	0.47	0.18	0.08	Prior art
1i	4.32	1.43	0.48	0.18	0.10	Prior art
1j	4.20	1.38	0.50	0.17	0.07	Prior art
1k	4.17	1.41	0.49	0.18	0.11	Invention
1l	4.17	1.41	0.49	0.18	0.11	Invention
1m	4.18	1.46	0.47	0.18	0.09	Invention
1n	4.18	1.46	0.47	0.18	0.09	Invention
1p	3.99	1.31	0.40	0.08	0.03	Invention
1q	3.99	1.31	0.40	0.08	0.03	Invention

Table 2

Example	Final thickness	Output T	R_m(L)	$R_{p0.2}$ (L)	A% (L)	R_m (TL)	$R_{p0.2}$ (TL)	A% (TL)	Forming limit diagram				LDH
									L = 500 mm		L = 300 mm		
	[mm]	[°C]	[MPa]	[MPa]	[%]	[MPa]	[MPa]	[%]	ε_1	ε_2	ε_1	ε_2	[mm]
1a (inv)	1.6 *	307	262	236	5.3	272	244	5.8	0.23	0.21	0.12	0.05	48.7
1b (inv)	6.3	286	213	153	14.5	217	164	13.7	0.46	0.37	0.34	0.21	82.2
1c	1.6 *	302	260	240	5.1	274	248	4.3	0.13	0.12	0.12	0.07	36.0
1d	6.0	261	232	166	12.1	232	177	11.6	0.29	0.25	0.27	0.08	68.6
1e	8.0	266	249	198	10.9	253	216	9.1					
1f	6.0	270	237	183	11.7	238	199	10.4					
1g	6.0	275	241	187	10.7	239	201	9.9					
1h	6.0	298	220	163	12.5	218	178	11.6					
1i	4.0	296	226	175	11.9	226	192	10.6					
1j	9.4	276	224	172	12.0	224	186	10.5					
1k (inv)	5.0	335	201	146	16.4	201	157	16.1					
1L (inv)	5.0	332	201	146	16.7	201	158	15.8					
1m (inv)	5.0	315	209	158	15.1	210	173	14.3					
1n (inv)	5.0	331	199	145	15.5	200	159	15.7					
1p (inv)	6.0	333	192	136	16.3	190	147	16.9					
1q (inv)	6.0	335	191	137	17.3	191	149	16.8					

(*) obtained by cold rolling, final hot rolling thickness: 4.0 mm (ex. 1a) or 4.1 mm (ex 1c).

It appears that the correct choice of the chemical composition, suggested by WO 96/29440, is not enough in itself to improve forming ability in accordance with the object of this invention. On the other hand, the applicant has noticed that the choice of a hot rolling output temperature results in improved forming ability, expressed as ultimate elongation A, whereas the influence of the chemical composition (in particular Cu < 4.3 and preferably < 4.2; Si < 0.10; Fe < 0.10) is only a secondary one.

It appears that the inventive method provides a better ability to forming in F temper, expressed as A% of LDH or forming limit diagram, than the prior art method. More particularly, a cold rolled coil according to the invention has an LDH value greater than 42 mm and preferably greater than 44 mm, whereas a hot rolled coil has an LDH value greater than 73 and preferably greater than 75 mm. It also appears that for a given thickness, the preferred composition yields better forming ability than the traditional composition.

The mechanical characteristics of the intermediate product (R_m, $R_{p0.2}$, etc.) are not important in this situation, provided the final product at the end of the whole process has mechanical characteristics that are at least as good as the product resulting from the prior art method. In T42 temper, such as defined by the draft standard prEN 4211 of July 1995, for a 6 mm thickness and with the same manufacturing range, both products have equivalent mechanical properties.

For the method according to the invention, a cumulated influence of the hot rolling output

temperature (ex. 1^e and 1j compared to 1k and 1n) and of the chemical composition (ex. 1p and 1q compared to 1k and 1n) is also apparent.

The LDH value and the forming limit diagram level are lower for a strain hardened sheet than for a sheet that has only undergone hot rolling; this effect is well known. On the other hand, the applicant was surprised to notice that for a given process (hot rolling or hot rolling with subsequent cold rolling) and at comparable thickness, the LDH value, which is one of the parameters relevant for measuring forming ability, increases significantly when the chemical composition is within a preferred range: Cu 3.9 - 4.3 and preferably 3.9 - 4.2, Mg 1.2 - 1.4 and preferably 1.25 - 1.35, Mn 0.30 - 0.45, Si < 0.10 and preferably < 0.08, Fe < 0.10. Moreover, the applicant has found out that forming ability is further improved when certain alloying and impurity elements are strictly controlled, as follows: Zn < 0.20%, Cr < 0.07% and preferably < 0.05%, Zr < 0.07% and preferably < 0.05%, Ti 0.07% and preferably < 0.05%.

Example #2

Various alloys were prepared, the compositions of which are indicated in Table 3. Rolling plates were cast, scalped, then homogenized at a temperature between 470°C and 510°C for 2 hrs to 12 hrs. After cladding with a 1050 alloy, the plates were hot rolled (process abbreviated as "HR") up to a final thickness greater than or equal to 4 mm; for lower thicknesses, the coils were cold rolled. When the coils had been cut

up into sheets, they were subjected to a solution treatment typical for this type of alloy (see prEN 4211 of July 95), quenched and characterized 30 minutes after quenching. Results are collected in Table 4. In order to be able to compare the samples strictly, solution treatment and quenching were carried out on ready-made test pieces, and for each mechanical property characterization, strain started exactly 30 minutes after the end of quenching. Examples 2a, 2b, 2e, 2j, 2k, 2n correspond to this invention. Examples 2h, 2L, 2m, 2p correspond to prior art.

For a comparable thickness, it appears that the inventive method results in better forming ability in W temper, as is apparent from the following properties: total elongation A%, distributed elongation A_g, plane tensile elongation A_{tp}, LDH, forming limit diagram. As far as the forming limit diagram is concerned, it appears that in the case of the invention, for a 5 mm thick sheet (ex. 2n), in contrast to a sheet according to prior art having virtually the same thickness (ex. 2p), a coefficient $\varepsilon_1 > 0.18$ for L = 500 mm, and $\varepsilon_2 > 0.22$ for L = 500 mm is obtained.

The advantage of the inventive method in comparison with prior art is therefore to be able to carry out deeper forming in W temper, or even to eliminate an intermediate solution treatment for very deep forming.

Thus, it has been possible to manufacture pieces in a single pass, whereas according to prior art, two passes were required to do so.

Table 3

Ex	Cu (%)	Mg (%)	Mn (%)	Fe (%)	Si (%)	coiling thickness after HR [mm]	coiling temp. after HR [°C]	Solution treatment	Final thickness [mm]
2a	4.12	1.29	0.49	0.17	0.08	4.0	290	496°C/ 13 min	1.6
2b	4.17	1.37	0.48	0.18	0.10	4.4	291	496°C/ 13 min	1.6
2^e	4.05	1.27	0.41	0.06	0.04	4.0	307	496°C/ 13 min	1.6
2h	4.39	1.48	0.63	0.18	0.09	4.0	287	496°C/ 13 min	1.6
2j	4.31	1.38	0.34	0.13	0.08	5.8	324	498°C/ 13 min	3.2
2k	4.15	1.32	0.39	0.078	0.040	5.8	279	498°C/ 13 min	3.2
2L	4.24	1.51	0.62	0.16	0.07	5.8	291	498°C/ 13 min	3.2
2m	4.35	1.51	0.64	0.19	0.11	5.9	307	498°C/ 13 min	3.2
2n	4.00	1.25	0.43	0.066	0.036	5.0	307	500°C/ 33 min	5.0
2p	4.32	1.41	0.50	0.17	0.09	5.1	325	498,5°C/ 23 min	5.1

TABLE 4

Ex	$R_{p0.2}$ [MPa]			R_m [MPa]			A [%]			A_g [%]			A_{tp} [%]			LDH	FLD			
																	L=500		L=300	
	TL	L	45°	TL	L	45°	TL	L	45°	TL	L	45°	TL	L	45°		ε_1	ε_2	ε_1	ε_2
2a	158	172	161	350	362	353	26.8	19.5	26.2	22.5	17.5	23.5	20.7	20.0	20.5					
2b	159	179	162	355	368	356	25.3	20.6	26.6	22	18.5	23.5	20.6	19.1	22.3					
2h	182	193	181	381	390	377	24.4	18.8	23.2	22.5	17.8	21.5	19.3	18.9	22.6					
2j	198	205	194	402	398	382	31.4	28	29.1	27.5	24.5	25.5	23.5	19.5	23.8					
2k	182	222	192	377	406	379	32	25.7	29.4	28.5	23	26	24.6	22.6	23.6					
2L	190	205	196	391	409	396	27.6	20.5	27.8	24.5	19.5	25	21.5	19.5	21.5					
2m	182	197	186	391	404	395	28.4	23	29.1	24.5	20.5	26	20.6	18.5	19.5					
2n	182	182		376	375		26.5	26.3								76.4	0.24	0.21	0.21	0.05
2p	188	195		373	380		27.1	25.3								75.4	0.20	0.16	0.14	0.04

Example #3

Various alloys were prepared, the compositions of which are indicated in Table 5. Rolling plates were cast, scalped, then homogenized at a temperature between 460°C and 510°C for 3 hrs to 6 hrs. After cladding with a 1050 alloy, the plates were hot rolled up to a final thickness greater than or equal to 4 mm; for lower thicknesses, the coils were cold rolled. Sheets cut out of these coils were subjected to a solution treatment typical for this type of alloy indicated in Table 6 (see prEN 4211 of July 95), quenched, aged (at least 48 hrs at ambient temperature). Then, smooth out cold working was carried out, followed by controlled stretching with a target permanent set of 1.5%. Results are collected in Table 6.

Examples 3s, 3t, 3u, 3v, 3w, 3x correspond to this invention. Examples 3e, 3f, 3g, 3h, 3i, 3j, 3k, 3L, 3m, 3n, 3p, 3q, 3r correspond to prior art. Examples 3a, 3b, 3c, 3d correspond to examples 2h, 2f, 2L, and 2m of example 2; they appear here by way of comparison in order to represent a prior art W temper 2024.

When the sheets used in the inventive method (composition optimized in T3 temper) are compared with sheets used in prior art methods, i.e. a 2024 alloy in T3 (examples 3s, 3t, 3u, 3v, 3w) or W (examples 3a, 3b, 3c, 3d) temper, it appears that for a given thickness, the inventive method results in better forming ability, as is apparent from ultimate elongation and above all from LDH and FLD values. Springback is less than in prior art.

More specifically, when the chemical composition is in the preferred range, the method results in an improvement of forming ability as characterized by the parameters that have just been listed. It is possible to carry out forming much stricter than in prior art T3 temper, or even to eliminate solution treatment because the inventive method results in a T3 temper product with forming ability properties at least as good as that of the prior art method W temper product.

Furthermore, drawing was carried out on two sheets, resulting in a total elongation of 3% or 5%, and damage tolerance properties were measured before and after drawing, i.e. toughness K_{C0} and K_C in the directions T-L and L-T. In addition, mechanical characteristics were measured in the T-L direction. The results are collected in Table 7.

It appears that after draw forming, the inventive method does not result in a significant reduction of damage tolerance properties, contrary to the prior art method. It even appears that the inventive method improves damage tolerance in elongated temper, which is the temper of the final piece.

TABLE 5

Ex	Cu (%)	Mg (%)	Mn (%)	Fe (%)	Si (%)	Coiling thickness after HR [mm]	Coiling temp. after HR [°C]	Solution treatment	Final thicknes s [mm]	
3a	4.39	1.48	0.63	0.18	0.09	4.0	287	496°C/13 min	1.6	ant
3b	4.14	1.38	0.50	0.14	0.07	4.2	304	498.5°C/13 min	2.0	ant
3c	4.24	1.51	0.62	0.16	0.07	5.8	291	498°C/13 min	3.2	ant
3d	4.35	1.51	0.64	0.19	0.11	5.9	307	498°C/13 min	3.2	ant
3e	4.32	1.41	0.50	0.17	0.09	5.1	325	498.5°C/23 min	5.1	inv
3f	4.12	1.29	0.49	0.17	0.08	4.0	290	496.5°C/11 min	1.6	inv
3g	4.15	1.32	0.39	0.078	0.040	4.0	284	500°C/20 min	1.6	inv
3h	4.00	1.25	0.43	0.066	0.036	4.0	307	498°C/11 min	1.8	inv
3i	4.15	1.28	0.40	0.10	0.05	4.0	304	498.5°C/13 min	1.6	inv
3j	4.05	1.27	0.41	0.06	0.004	4.0	307	496°C/11 min	1.6	inv
3k	4.20	1.42	0.48	0.176	0.087	5.8	327	498.5°C/20 min	3.2	inv
3L	4.31	1.38	0.34	0.13	0.08	5.8	324	498.5°C/19 min	3.2	inv
3m	4.15	1.32	0.39	0.078	0.040	5.8	279	500°C/40 min	3.2	inv
3n	4.15	1.32	0.39	0.078	0.040	5.8	279	498.5°C/19 min	3.2	inv
3p	4.31	1.38	0.34	0.13	0.08	6.4	331	498°C/19 min	4.0	inv
3q	4.15	1.32	0.39	0.078	0.040	6.5	254	500°C/45 min	6.4	inv
3r	4.00	1.25	0.43	0.066	0.036	5.0		500°C/33 min	5.0	inv
3s	4.39	1.48	0.63	0.18	0.09	4.0	287	496.5°C/11 min	1.6	ant
3t	4.14	1.38	0.50	0.14	0.07	4.0	308	498.5°C/13 min	2	ant
3u	4.30	1.38	0.51	0.15	0.07	4.0	304	496.5°C/11 min	1.6	ant
3v	4.35	1.51	0.63	0.19	0.11	5.8	314	498.5°C/19 min	3.2	ant
3w	4.32	1.41	0.50	0.17	0.09	5.1	325	498.5°C/23 min	5.1	ant
3x	4.00	1.25	0.43	0.066	0.036			500°C/30 min	1.6	inv

TABLE 6

Ex	th.	$R_{p0.2}$ [MPa]			R_m [MPa]			A [%]			A_g [%]			A_{tp} [%]			LDH	FLD				Resi-lience
																		L = 500		L = 300		
	mm	TL	L	45°	TL	L	45°	TL	L	45°	TL	L	45°	TL	L	45°		ε_1	ε_2	ε_1	ε_2	
3a/ ant	1.6	182	193	181	381	390	377	24.4	18.8	23.2	22.5	17.8	21.5	19.3	18.9	22.2						0.15
3b/ ant	2.0	177	175		373	374		24	22.6								66.9	0.16	0.15	0.15	0.05	
3c/ ant	3.2	190	205	196	391	409	396	27.6	20.5	27.8	24.5	19.5	25.0	21.5	19.5	21.5						
3d/ ant	3.2	182	197	186	391	404	395	28.4	23	29.1	24.5	20.5	26	20.6	18.5	19.5						
3e/ ant	5.1	188	195		373	380		27.1	25.3								75.4	0.20	0.16	0.14	0.04	
3f/ inv	1.6	309	346	309	436	449	433	19	18	23	16.5	16.5	20.5	16	17.8	19	70.4					
3g/ inv	1.6	302	349	312	435	448	433	21.2	19.2	21.9	18.5	17.5	19.5	20.7	16.4	19.6	74.8					
3h/ inv	1.8	295	335		433	448		22.0	17.5								72.5	0.23	0.14	0.20	0.02	
3i/ inv	1.6	290			428			24.6									76.2					
3j/ inv	1.6	277			430			20														0.12
3k/ inv	3.2	295	351	319	444	457	441	25.6	22.3	21.0	19.0	18.0	17.0	19.4	17.7	18.7	76.0					
3L/ inv	3.2	309	321	296	444	449	438	26.1	24.9	27.1	20.0	21.0	20.0	20.6	19.3	22.5	85.4					
3m/ inv	3.2	302	348	302	442	456	438	25.3	22.5	27.3	19.5	18.0	22.0	20.4	19.2	22.1	81.7					
3n/ inv	3.2	310	334	304	441	455	433	25.4	22.2	25.2	21.5	18.0	19.0	20.5	19.0	21.8						

3p/ inv	4.0	302	324	297	442	452	440	21.5	21.5	25.5	18.5	18.5	20.5	21.5	20.3	21.9	87.8					
3q/ inv	6.4	307	341	316	448	458	446	22.6	22.9	23.4	18.5	19.5	17.5	22.7	23.3	25.5	84.7					
3r/ inv	5.0	300	320		429	438		21.9	21.8								80.5	0.27	0.22	0.20	0.03	
3s/ ant	1.6	318	368	322	459	463	443	17.8	16.4	19.4	14.5	13.5	15.5	14.8	15.1	17.6	69.0					0.14(**)
3t/ ant	2.0	302	334		438	444		19.5	20.4								70.0	0.17	0.14	0.15	0.03	
3u/ ant	1.6	317	362		445	453		20.1	18.3													
3v/ ant	3.2	327	364	338	458	471	457	19.5	20.4	22.2	16.0	16.5	17.5	18.8	16.7	20.5	71.1					
3w/ ant	5.0	307			446			21.5									75.4	0.17	0.16	0.13	0.02	
3x/ inv	1.6	295	320		432	437		24.1	23.9								77.0					

TABLE 7

Ex	$R_{p0.2}$ (TL) [MPa]	R_m (TL) [MPa]	A %	K_{C0} (T-L) [MPa√m]	K_C (T-L) [MPa√m]	K_{C0} (L-T) [MPa√m]	K_C (L- T) [MPa√m]
3u	317	445	20.1	78	122	93.1	139.6
3u (*)	353	455	17	74.1	103.6	88.5	116.3
3x	295	432	24.1	81.6	137.7	91	148.3
3x (*)	358	455	16.2	85.6	129.7	93.3	137.5
3x (£)	344	452	18.8	84.2	131.3	95.4	138.5

(*) after 5% total elongation upon T4 temper

(£) after 3% total elongation

CLAIMS

1. A method of manufacturing highly worked pieces of AlCuMg alloy, comprising the steps of:

a) casting a plate composed of (weight per cent): Cu: 3.8 - 4.5 Mg: 1.2 - 1.5 Mn: 0.3 - 0.5 Si < 0.25 Fe < 0.20 Zn < 0.20 Cr < 0.10 Zr < 0.10 Ti < 0.10

b) possibly homogenizing at a temperature between 460 and 510°C for 2 to 12 hrs, and preferably at a temperature of 470 and 500°C for a duration of 3 to 6 hrs,

c) hot rolling at an input temperature between 430 and 470°C, and preferably between 440 and 460°C,

d) possibly cold rolling the coil,

e) possibly annealing the coil at a temperature between 350 and 450°C,

f) cutting out sheets,

g) solution treating between 480 and 500°C, for a duration between 5 min and 1 hr,

h) quenching,

i) forming in one or several processes, such as stretch forming, drawing, flow spinning, or bending, wherein such forming may also take place after step f).

2. The method according to claim 1, characterized in that a first forming takes place before solution treatment and in that, after solution treatment and quenching, the formed piece is submitted to the following process:

a) possibly immediately transferring the piece in as quenched condition into a cold chamber at a

temperature of less than 10°C, and preferably of less than 0°C,

b) less than one hour after quenching or leaving the cold chamber, another sheet forming in one or several processes, such as stretch forming, drawing, flow spinning, or bending.

3. The method of manufacturing highly worked pieces of AlCuMg alloy according to claim 1, comprising sheet manufacturing through the following steps:

a) casting a plate composed of (weight per cent): Cu: 3.8 - 4.5 Mg: 1.2 - 1.5 Mn: 0.3 - 0.5 Si < 0.25 Fe < 0.20 Zn < 0.20 Cr < 0.10 Zr < 0.10 Ti < 0.10,

b) possibly homogenizing at a temperature between 460 and 510°C for 2 to 12 hrs, and preferably at a temperature between 470 and 500°C for a duration of 3 to 6 hrs,

c) hot rolling at an input temperature between 430 and 470°C, and preferably between 440 and 460°C,

d) cutting out sheets,

wherein, in the L and LT directions, the sheets have an ultimate elongation A greater than 13.5%, and preferably greater than 15%, and are used for manufacturing highly worked pieces through the following steps:

e) sheet forming in one or several processes, such as stretch forming, drawing, flow spinning, or bending,

f) solution treating formed pieces at a temperature between 480 and 500°C, for a duration of 5 min and 1 hr,

g) quenching.

4. The method according to any of claims 1 to 3, characterized in that the sheet is cladded on one side or on both sides with another sheet of aluminium alloy.

5. The method according to any of claims 3 to 4, characterized in that the hot rolling output temperature is > 300°C, and preferably > 310°C.

6. The method according to any of claims 1 to 5, characterized in that cold rolling is carried out between hot rolling and sheet cutting.

7. The method according to any of claims 1 to 6, characterized in that Cu content is between 3.9 and 4.3%, and preferably between 3.9 and 4.2%.

8. The method according to any of claims 1 to 7, characterized in that Mg content is between 1.2 and 1.4%, and preferably between 1.25 and 1.35%.

9. The method according to any of claims 1 to 8, characterized in that Mn content is between 0.30 and 0.45%.

10. The method according to any of claims 1 to 9, characterized in that Si content is less than 0.10%, and preferably less than 0.08%.

11. The method according to any of claims 1 to 10, characterized in that Fe content is less than 0.10%.

12. The method according to any of claims 1 to 11, characterized in that Zn < 0.20%, Cr < 0.07%, and preferably < 0.05%, Zr < 0.07%, and preferably < 0.05%, Ti 0.07%, and preferably < 0.05%.

13. The method of manufacturing highly worked pieces of AlCuMg alloy according to claim 1, comprising the following steps of:

a) casting a plate composed of (weight per cent): Cu: 3.8 - 4.5 Mg: 1.2 - 1.5 Mn: 0.3 - 0.5 Si < 0.25 Fe < 0.20 Zn < 0.20 Cr < 0.10 Zr < 0.10 Ti < 0.10,

b) possibly homogenizing at a temperature between 460 and 510°C for 2 to 12 hrs, and preferably at a temperature between 470 and 500°C for a duration of 3 to 6 hrs,

c) hot rolling at an input temperature between 430 and 470°C, and preferably between 440 and 460°C,

d) possibly cold rolling,

e) cutting out sheets,

f) solution treating the sheets at 480 to 500°C for a duration of 5 min and 1 hr,

g) quenching,

h) forming the sheets in one or several processes, such as stretch forming, drawing, flow spinning, or bending.

14. The method according to claim 13, characterized in that Cu content is between 3.9 and 4.3%, and preferably between 3.9 and 4.2%.

15. The method according to any of claims 13 or 14, characterized in that Mg content is between 1.2 and 1.4%, and preferably between 1.25 and 1.35%.

16. The method according to any of claims 13 or 15, characterized in that Mn content is between 0.30 and 0.45%.

17. The method of manufacturing highly worked pieces of AlCuMg alloy according to any of claims 13 to 16, comprising sheet manufacturing through the following steps:

a) casting a plate composed of (weight per cent): Cu: 4 - 4.5 Mg: 1.25 - 1.45 Mn: 0.30 - 0.45 Si < 0.10 Fe < 0.20 Zn < 0.20 Cr < 0.05 Zr < 0.03 Ti < 0.05,

b) possibly homogenizing at a temperature between 460 and 510°C for 2 to 12 hrs, and preferably at a temperature between 470 and 500°C for a duration of 3 to 6 hrs,

c) hot rolling at an input temperature between 430 and 470°C, and preferably between 440 and 460°C,

d) possibly cold rolling,

e) cutting out sheets,

f) solution treating the sheets at a temperature between 480 and 500°C for 5 min to 1 hr,

g) quenching,

wherein the sheets are used for manufacturing highly worked pieces in one or several processes, such as stretch forming, drawing, flow spinning, or bending.

18. The process to any of claims 13 to 17, characterized in that forming is carried out less than one hour after quenching.

19. The method according to any of claims 13 to 17, characterized in that between quenching and forming, the sheet in as quenched condition is stored in a cold chamber at a temperature of less than 0°C.

20. The method according to any of claims 18 to 19, characterized in that, for a thickness of 5 mm, the hot rolled sheet has a forming limit diagram characterized by a value $\varepsilon_1 > 0.18$ for L = 300 mm, or $\varepsilon_1 > 0.22$ for L = 500 mm.

21. The method according to any of claims 13 and 17, characterized in that between quenching and forming, cold working is performed through rolling or smooth out, followed by controlled stretching with permanent set between 0.5 and 5%.

22. The method according to claim 21, characterized in that the sheet that was solution treated, quenched, cold worked through rolling or smooth out, and possibly stretched with permanent set between 0.5 and 5% has at least one of the following sets of properties:

a) - a mean value of the three elongation A values measured in the directions TL, L and at 45°, greater than 20% and preferably greater than 22%, and

- a mean value of the three values $R_{p0.2}$ measured in the directions TL, L and at 45°, greater than 305 MPa, and

- an LDH value greater than 72 mm for a thickness of 1.6 mm, or an LDH value greater than 76 mm for a thickness of 3.2 mm, or an LDH value greater than 80 mm for a thickness between 4 and 7 mm;

b) - a mean value of the three values $R_{p0.2}$ measured in the directions TL, L and at 45°, greater than 305 MPa, and

- a mean value of the three values Ag measured in the directions TL, L and at 45°, greater than 18%;

c) - a mean value of the three elongation A values measured in the directions TL, L and at 45°, greater than A > 22%, and

- a mean value of the three values $R_{p0.2}$ measured in the directions TL, L and at 45°, greater than 305 MPa, and

- a mean value of the three values Ag% measured in the directions TL, L and at 45°, greater than 18%;

d) - a mean value of the three values $R_{p0.2}$ measured in the directions TL, L and at 45°, greater than 305 MPa, and

- a mean value of the three plane stretching Atp values measured in the directions TL, L and at 45°, greater than 18%,

- an LDH value greater than 72 mm for a thickness of 1.6 mm, or an LDH value greater than 76 mm for a thickness of 3.2 mm, or an LDH value greater than 80 mm for a thickness between 4 and 7 mm.

23. The method according to any of claims 21 and 22, characterized in that the sheet that was solution treated, quenched, cold worked through rolling or smooth out and possibly stretched with permanent set between 0.5 and 5% has at least one of the three following properties:

a) the LDH value is greater than 40 mm for a thickness of less than 4 mm, or greater than 74 mm for a thickness greater than 4 mm,

b) the forming limit diagram shows a coefficient $\varepsilon_1 > 0,18$ for L = 500 mm for a thickness between 1.4 mm and 2 mm,

c) the forming limit diagram shows a coefficient $\varepsilon_1 > 0,35$ for L = 500 mm for a thickness between 5.5 mm and 8 mm.

24. The method according to any of claims 21 to 23, characterized in that the sheet that was solution treated, quenched, cold worked through rolling or smooth out and possibly stretched with permanent set between 0.5 and 5% has at least one of the following properties:

a) K_c (L-T) > 120 MPa$\sqrt{m}$

b) K_{c0} (L-T) > 90 MPa$\sqrt{m}$

c) K_c (T-L) > 125 MPa$\sqrt{m}$

d) K_{c0} (T-L) > 80 MPa$\sqrt{m}$

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Application No:	GB 0008506.8	**Examiner:**	Matthew Lawson
Claims searched:	1-24	**Date of search:**	8 November 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): C7A

Int Cl (Ed.7): C22C; C22F 1/057

Other: Online: PAJ, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 0473122 A1	(ALCOA) - the whole specification.	1-24
X	EP 0157600 A2	(ALCOA) - the whole specification.	1-24
X	EP 0038605 A1	(BOEING) - the whole specification.	1-24
X	WO 96/29440 A1	(KAISER) - page 16 line 2 - page 17 line 30, page 18 lines 16-23, page 20 line 25 - page 22 line 2 and the claims.	1-24
X	WO 91/11540 A1	(MARTIN) - the whole specification, especially page 1 lines 26-29.	1-24
X	US 5213639	(COLVIN) - the whole specification.	1-24
X	US 4816087	(CHO) - the whole specification.	1-24
X	US 3826688	(LEVY) - the whole specification.	1-24

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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